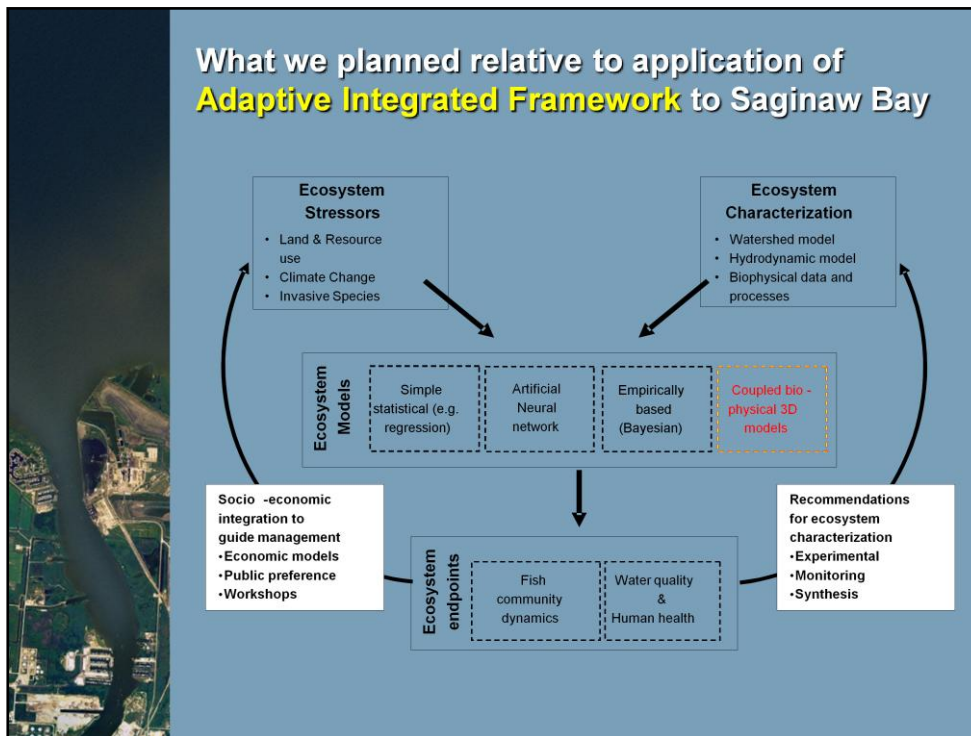
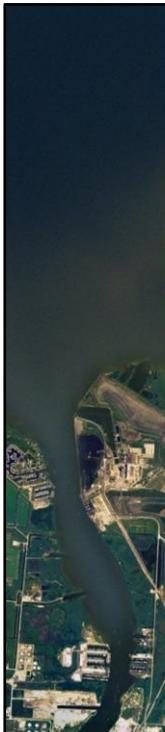




Craig asked us to present: what we planned, what we have accomplished, and our plan for the remainder of project.



Four categories of models are being developed in this study. Range of complexity and potential utility. Comparison of these models provides great value for both understanding and management support. Our role in this project is to build a linked, process-based, deterministic hydrodynamic – lower food web model for Saginaw Bay – the most complex of the model frameworks being developed.



Management Issues Addressed by SAGEM2

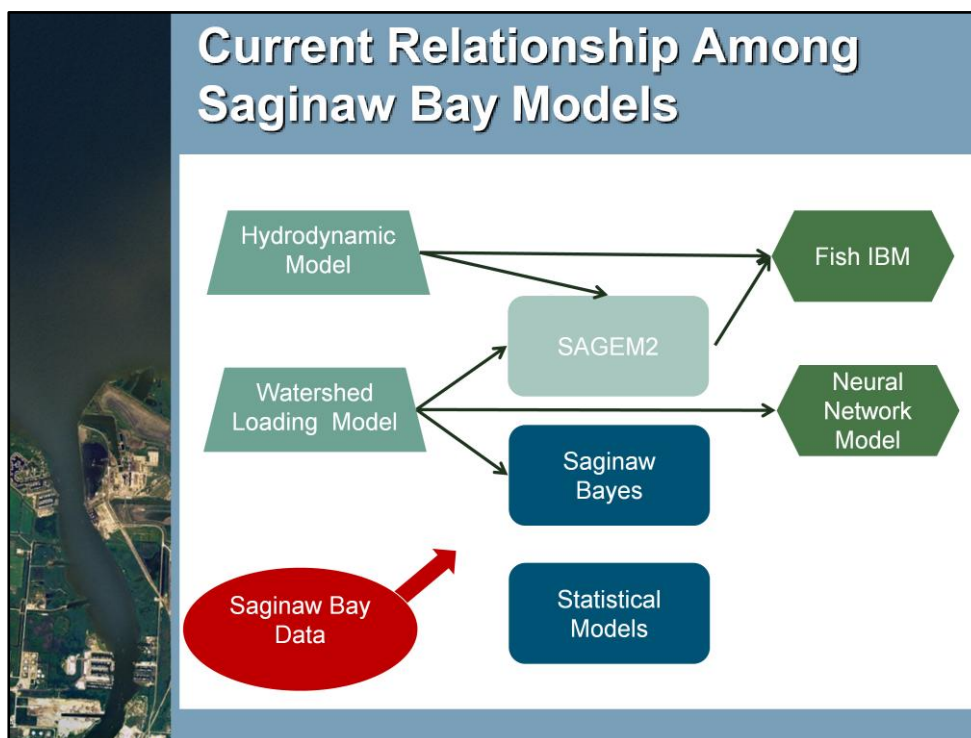
Quantify and explain the relative contribution of multiple stressors

- Nutrient loads
- Hydrology and water level
- Solids loads
- Dreissenids
- Temperature

to multiple water quality endpoints of concern.

- Nutrient concentrations/budgets
- HABs (*Microcystis*)
- Benthic algae (*Cladophora*, *Spirogyra*) and “muck” distribution
- Dissolved oxygen conditions
- Carrying capacity for upper food web
- Basically, determine the phosphorus load reduction necessary to reduce HABs (*Microcystis*) and benthic algae (*Cladophora*, *Spirogyra*) and “muck” distribution to acceptable levels under a plausible range of other stressor conditions.

Since only water quality management option is to control nutrient loads, we will focus on response to phosphorus loads. Also, managers have expressed a number of times the desire to answer the question of whether current target phosphorus loading needs to be adjusted to address the current problems in the bay.



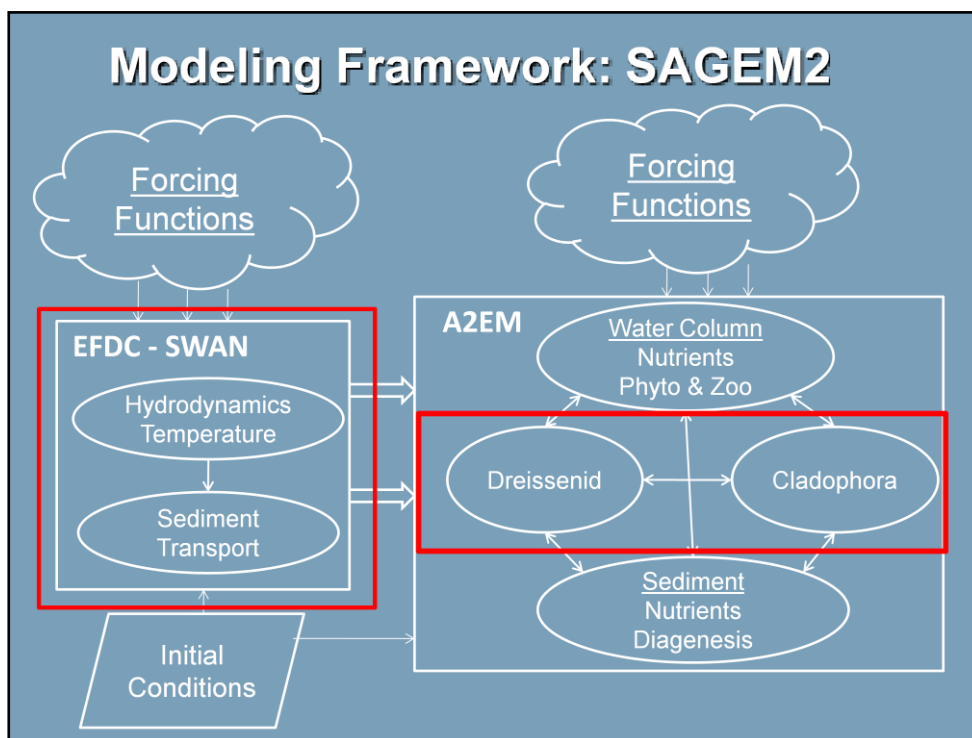
The management questions have guided model conceptual development necessary to address those questions in a quantitative way. Here is a picture of the various models being developed in this project and their relationship to each other. The models require data and are first used to identify data and knowledge gaps to help direct research and monitoring.



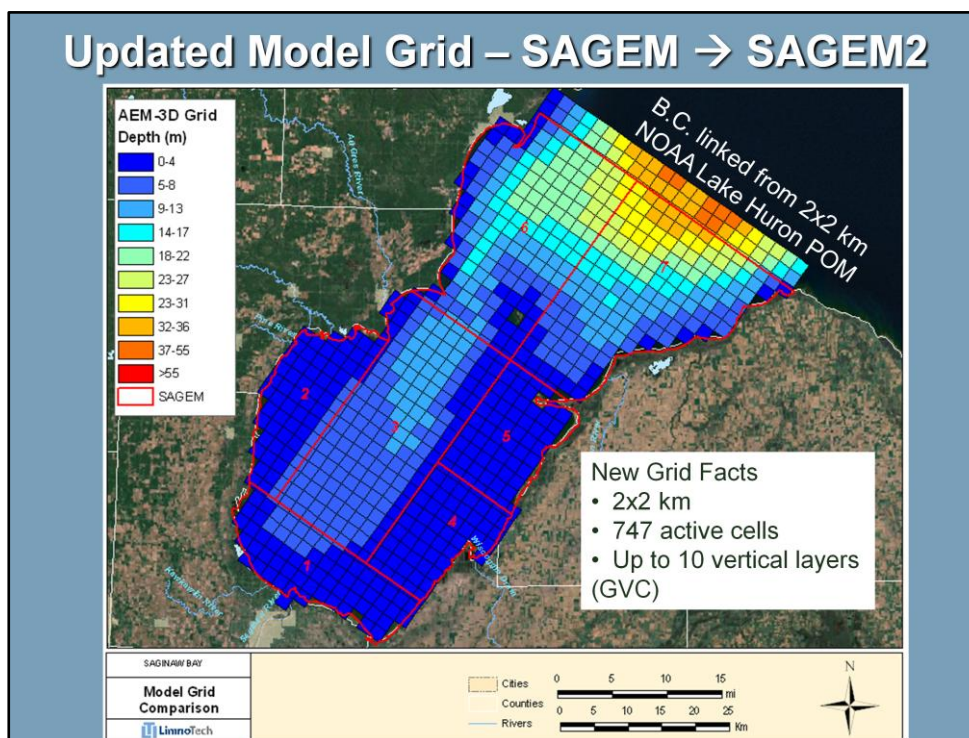
SAGEM2 Development Plan

1. Build SAGEM2 model
 - Update of SAGEM

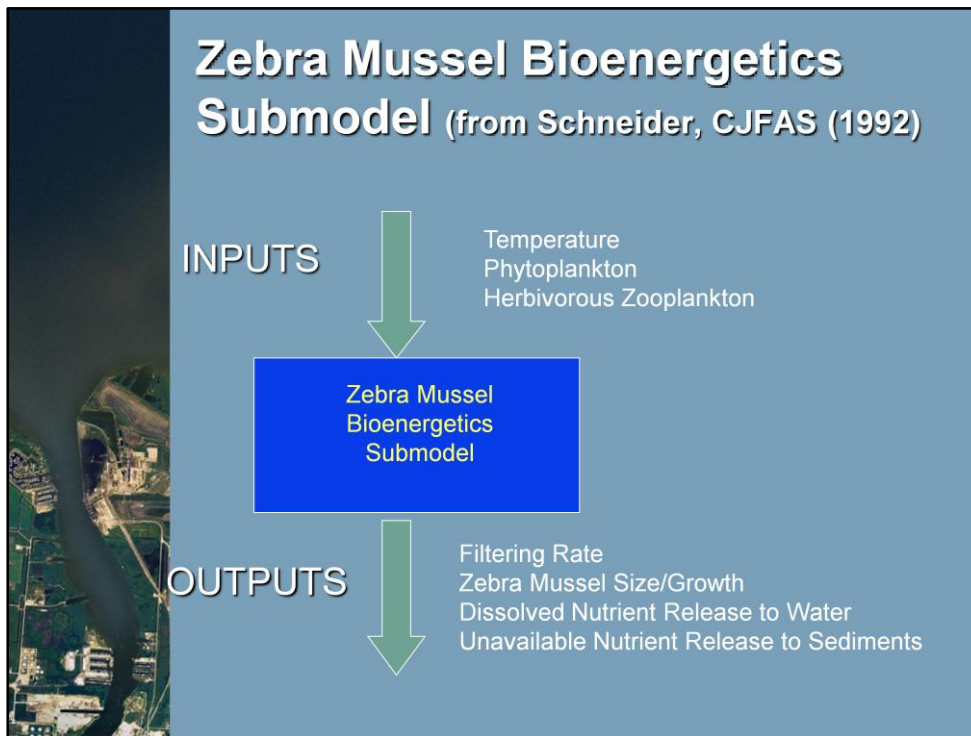
First step was to build the Saginaw Bay ecosystem model – started from previous Saginaw Bay ecosystem model.



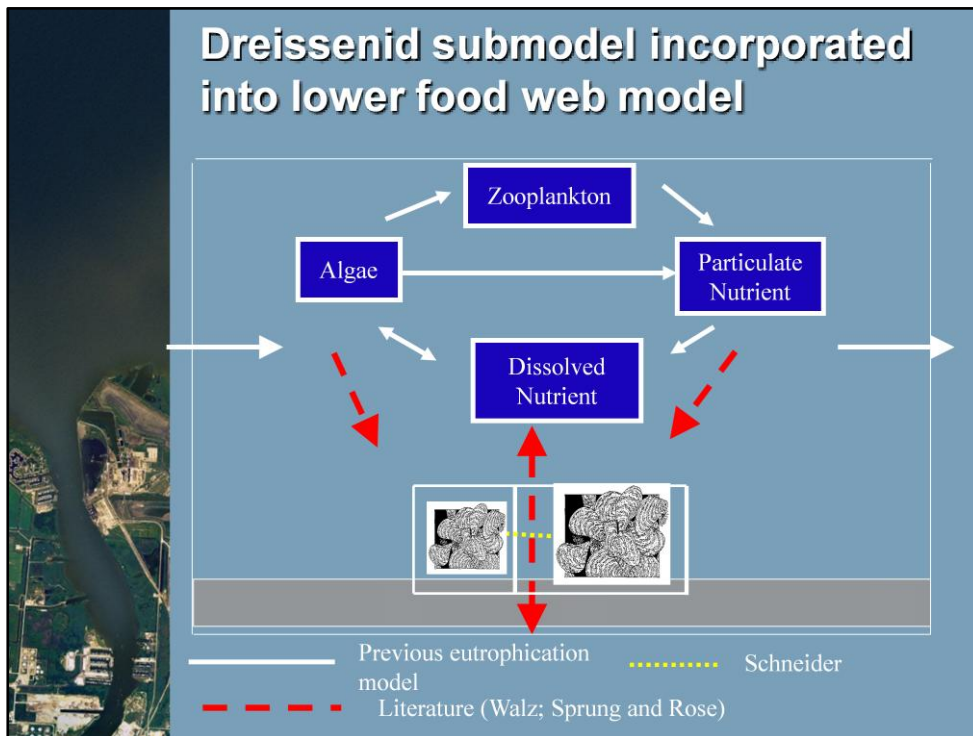
Linked EFDC-A2EM model – added dreissenid submodel from SAGEM (can model 3 cohorts of both zebra mussels and quagga mussels) and Auer's GLCM.



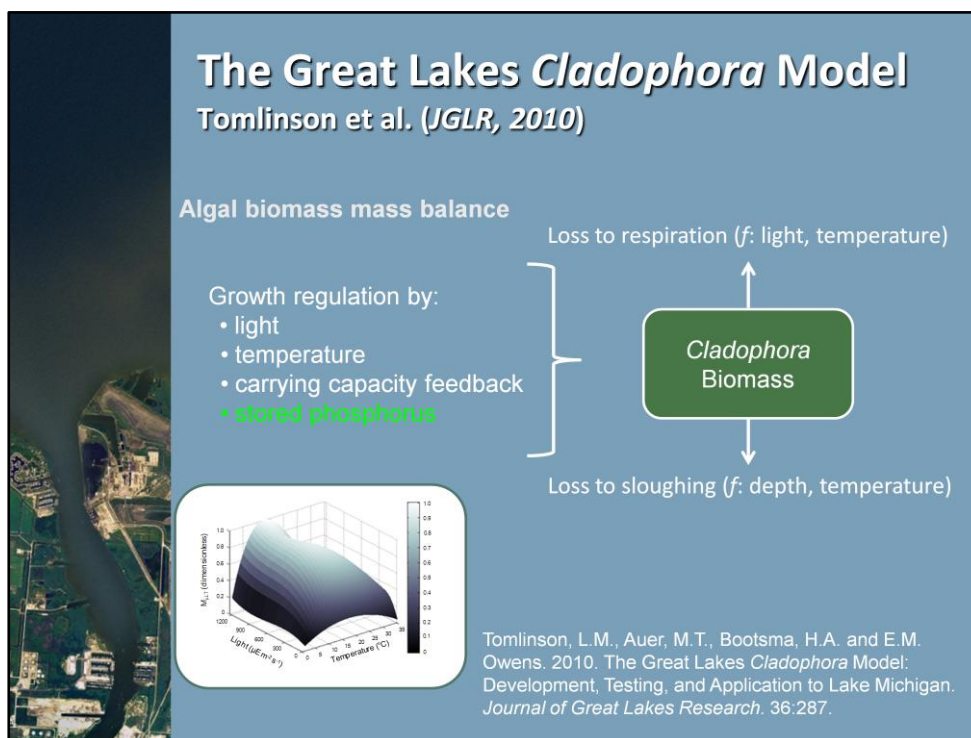
SAGEM2 has much finer grid than SAGEM – to capture important circulation and transport patterns in bay. GLERL whole lake POM model provides boundary conditions for exchange with main lake.



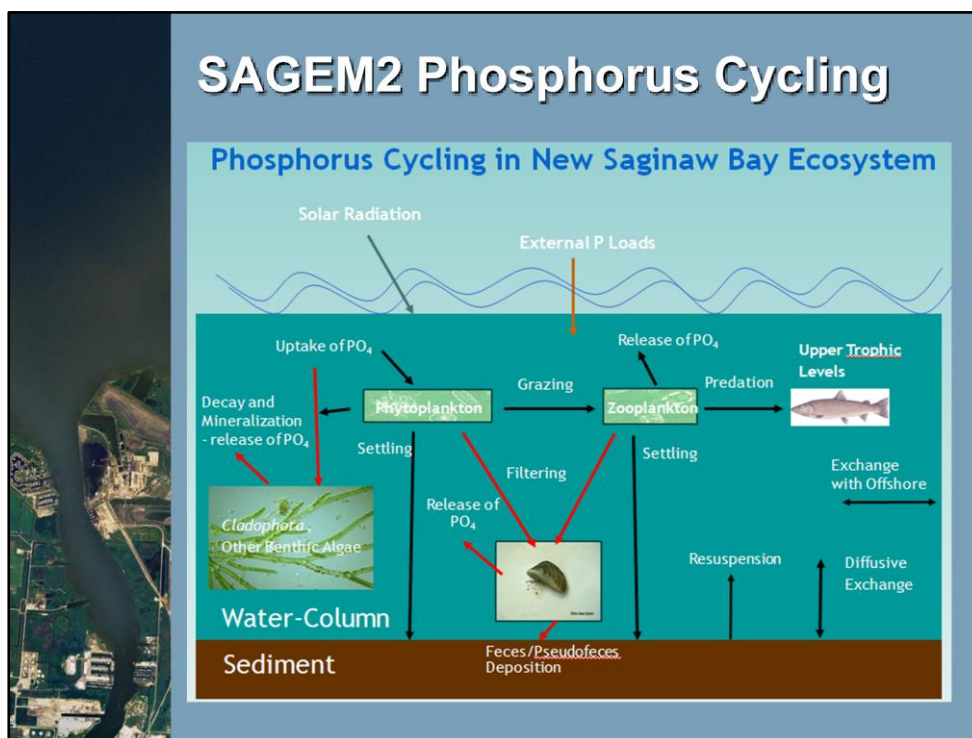
Dreissenid bioenergetics model developed from work of Schneider. We do not model Dreissenid population dynamics, just start with initial densities and grow mussels through the growing season.



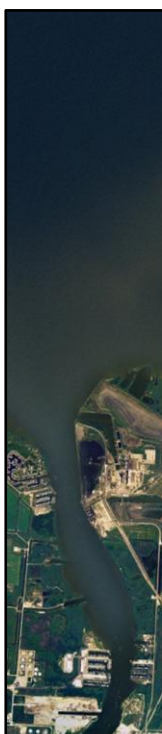
Dreissenids have been incorporated into SAGEM2 to account for the way they modify plankton, particulate detritus, and nutrient dynamics.



Cladophora submodel is taken from Auer's recent modeling work and also incorporated into plankton and nutrient dynamics of full SAGEM2.

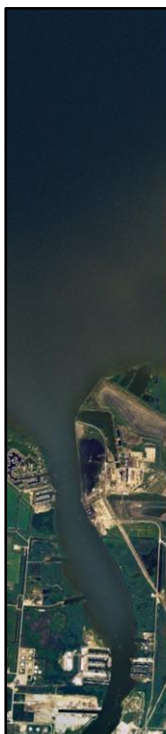


This slide shows how Dreissenids and Cladophora affect the other phosphorus cycling in SAGEM2.



SAGEM versus SAGEM2		
Category	SAGEM	SAGEM2
Hydrodynamic model	2D chloride mass balance 7 segments	3D model 2Km grid with 747 cells Up to 10 vertical layers
Sediment Transport – Resuspension	Calibrated empirical relationship with wind	Coupled SWAN (wind-wave model) with EFDC
Water Quality Model	Customized framework built from Bierman model	Documented and highly tested framework. Full sediment diagenesis sub-model
Benthic Algae Sub-model	Simple kinetics, attached green alga not specific to Cladophora	Auer Cladophora model (GLCM) with tracking of sloughed biomass
Filter Feeder Sub-model	1 species with 3 cohorts	2 species with 3 cohorts Complete mass balance

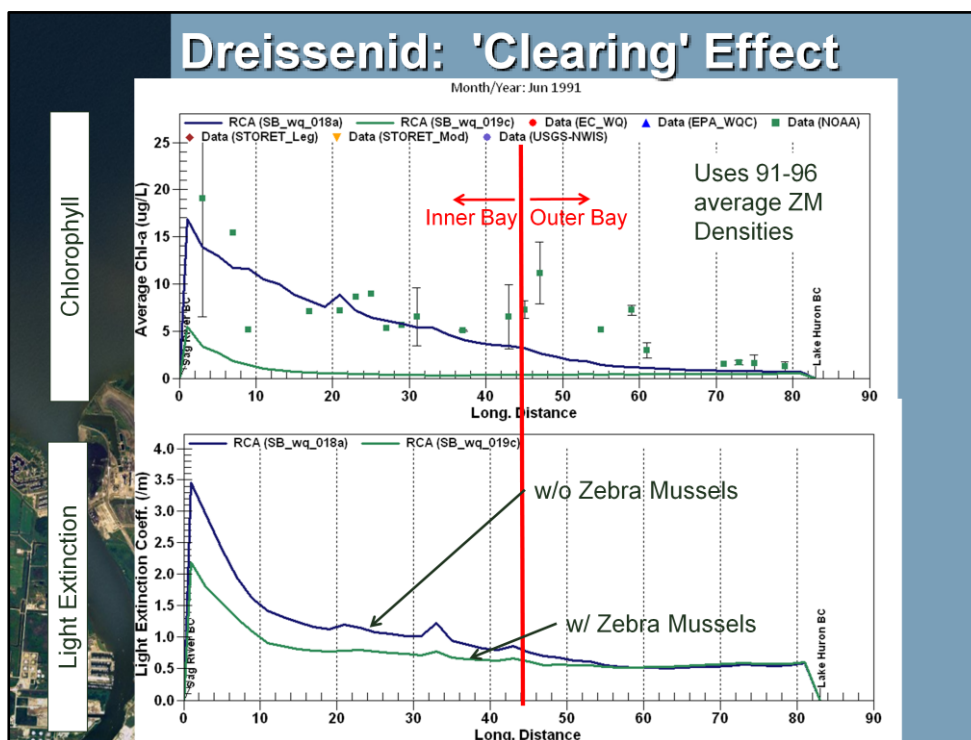
Summary of major refinements in SAGEM2 relative to SAGEM.



SAGEM2 Development Plan

1. Build SAGEM2 model
2. Application to 1991-96 Saginaw Bay data
 - Preliminary calibration
 - diagnostic analysis
 - Provide feedback for AIF process

Finished first two bullets

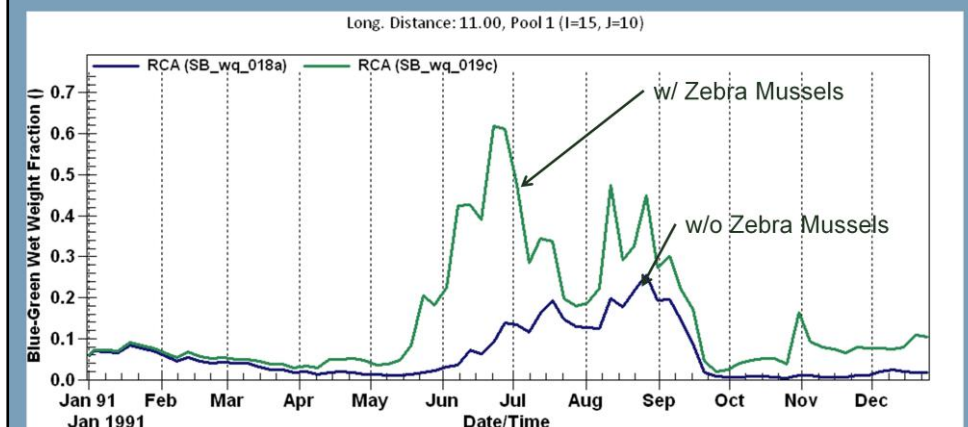


Example of the effect on chlorophyll and light extinction coefficient of including zebra mussels (at 1991-96 average densities) in SAGEM2 as applied to 1991.

Dreissenid: Selective Filtration

■ Dreissenid Filtration:

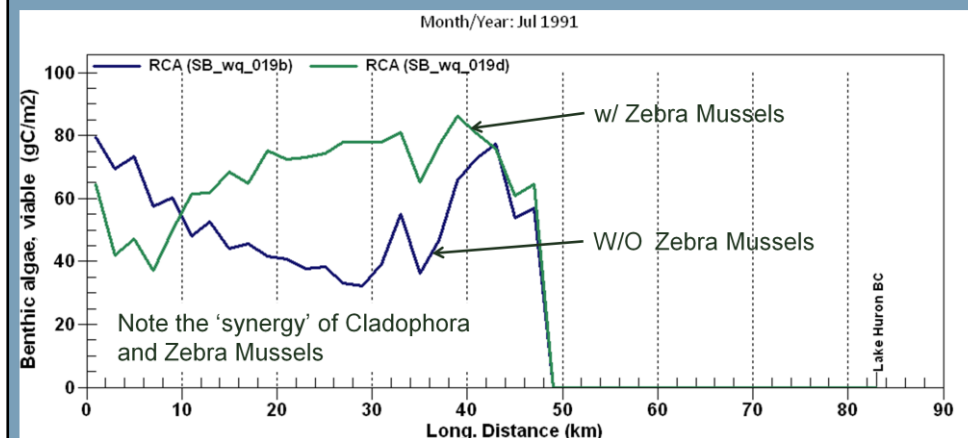
- Phytoplankton
- Zooplankton
- Organic sediment (POM)
- Inorganic sediment
- **Reject Blue-Greens**



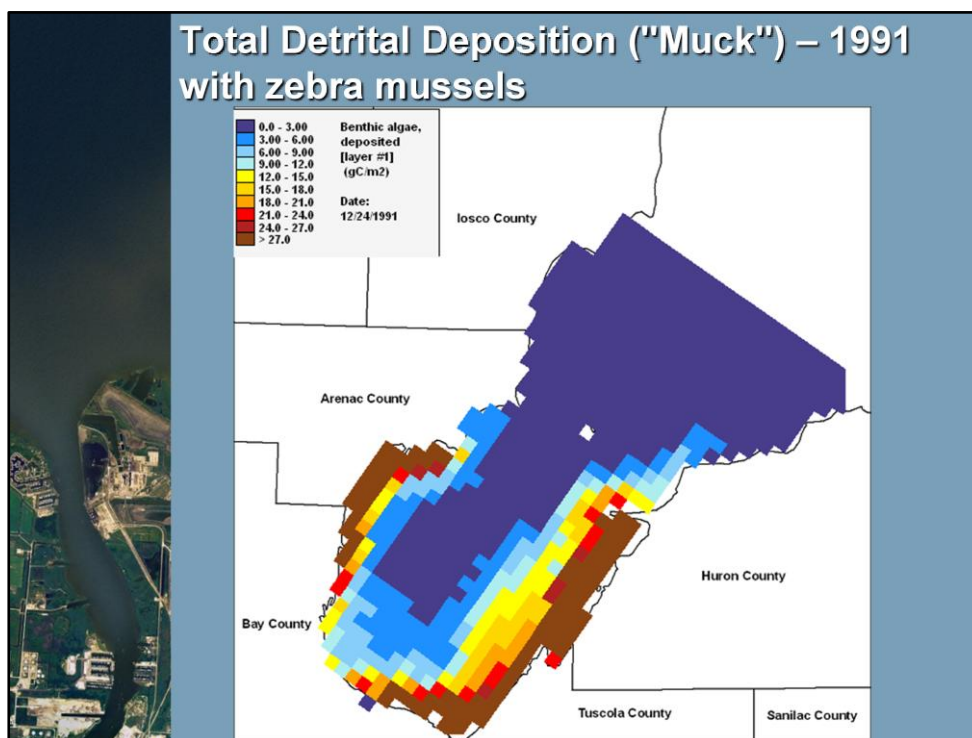
Altered sediment phosphorus recycle by dreissenids (late summer P release from sediments) and selective rejection of blue-greens are both necessary and sufficient to cause increase of *Microcystis* blooms in bay.

Benthic Algae Sub-model

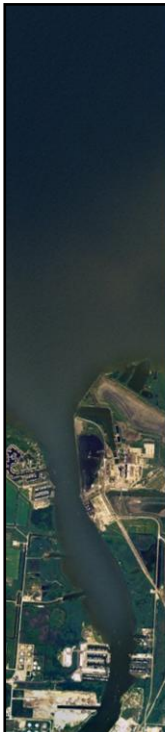
- Based on GLCM developed by M. Auer
- Model code is flexible to model any benthic or 'semi' benthic algae



Cladophora growth is enhanced by filtering action of Dreissenids – increased water clarity and increased phosphorus availability.



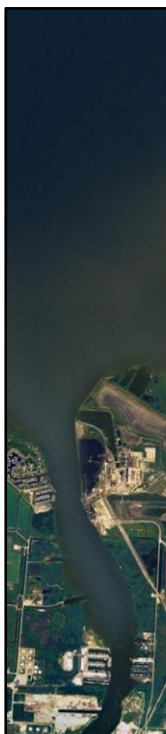
New state variable for detrital benthic algae has been added to the model to track transport of "muck" precursor material.



SAGEM2 recommendations for research and monitoring

- **Always have need for measurement of:**
 - Loads and forcing functions
 - Time and space observations of model state variables
- **Nutrient cycling through Dreissenids**
 - Mass balance of nutrients
 - Under a range of environmental conditions (temperature, quality of food, size/age, species)
- **Benthic primary production and nutrient dynamics**
 - Measurement of benthic algae biomass and dominant species (Cladophora?, Chara?, Spirogyra?)
 - Formation and characteristics of "muck"
- **Sediment fluxes of nutrients**
 - Measure nutrient fluxes under oxic and anoxic conditions (including SOD)
- **Develop empirical light extinction model – simultaneously measure:**
 - NVSS, Non-algal VSS, Algal VSS, DOM
 - Light extinction coefficient
- **Continuous monitoring buoy**
 - MET data and two WQ loggers (surface and near bottom)
 - Collect simultaneous turbidity data to evaluate wind-wave resuspension model

This slide gives an overview of the feedback and recommendations to the field and process researchers from our initial SAGEM2 modeling as to the process experimentation and field work that can have great value in reducing model prediction uncertainty by providing process rate coefficients for the model that have been seen to produce uncertainty as well as sensitivity in model output. Most of these recommendations have been addressed by project researchers.



SAGEM2 Development Plan

1. Build SAGEM2 model
2. Application to 1991-96 Saginaw Bay data
 - Preliminary calibration
 - diagnostic analysis
 - Provide feedback for AIF process
3. Calibrate with project data
 - 2009 – 2010

We have a preliminary run for 2009 using coefficients from the '91-'96 application work, except...next slide.

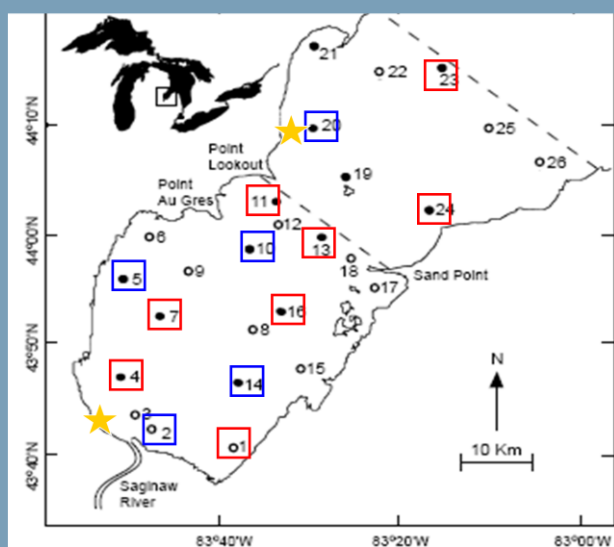


Initial SAGEM2 run for 2009

- Used our own estimates of loadings
- No parameter adjustment for calibration
- Did not include Dreissenids
 - Need to get density data
- Did not include wind-driven resuspension
 - SWAN not linked to model yet

The results presented below for our 2009 preliminary run have the following caveats and should not be considered final.

Saginaw Bay Sampling Stations

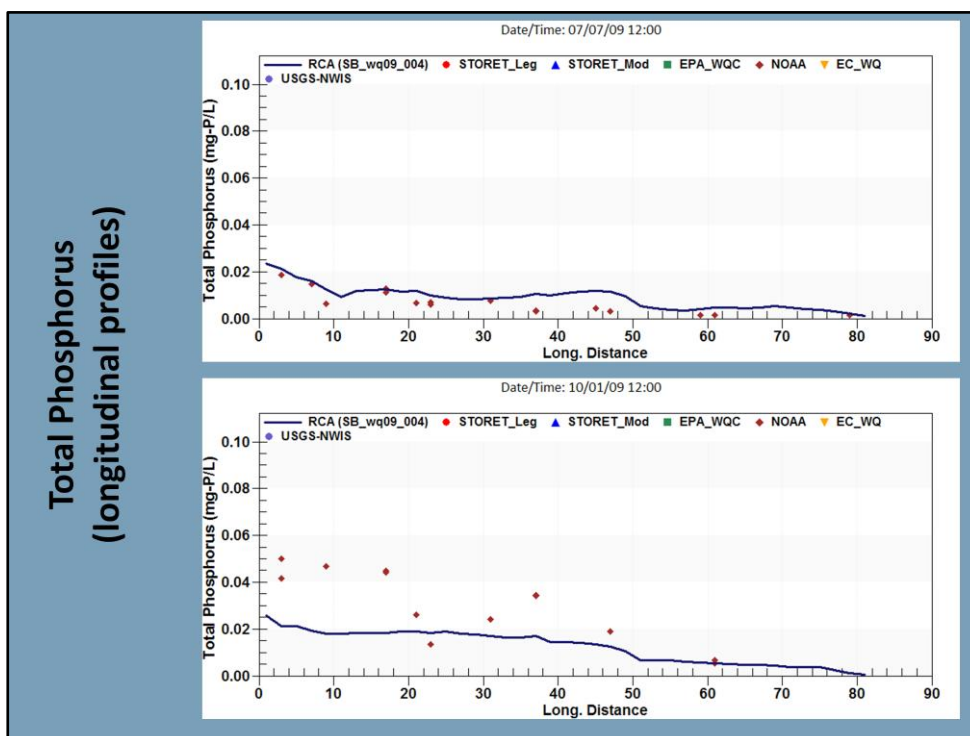


Blue: Master (5)

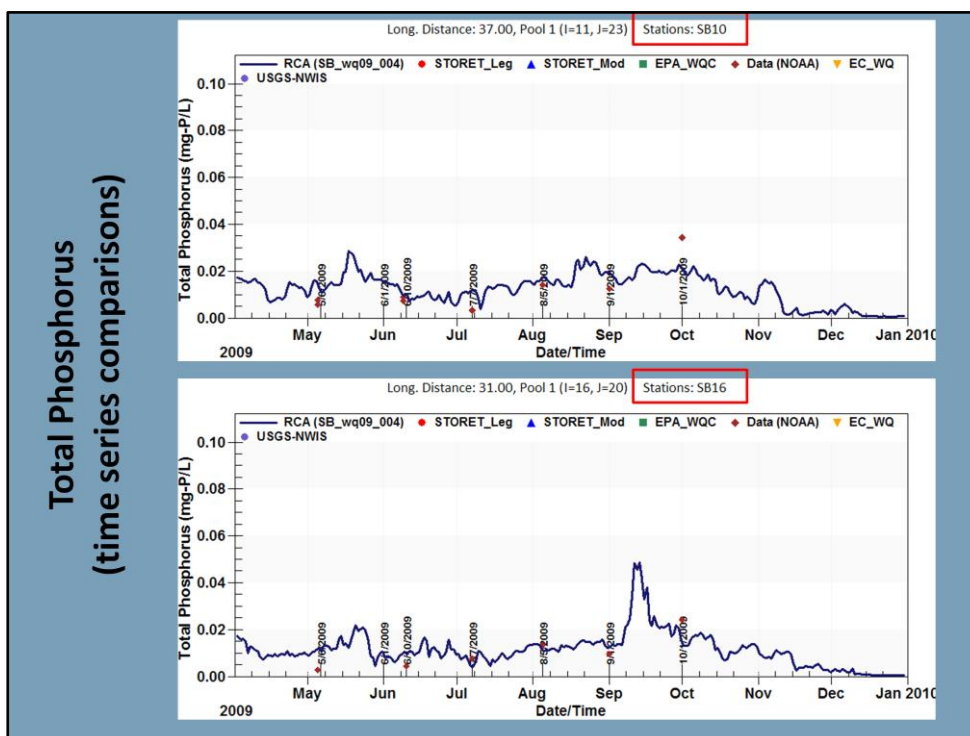
Red: Basic (8)

★ Water utility intakes

Calibration will make use of bay water quality sampling data.

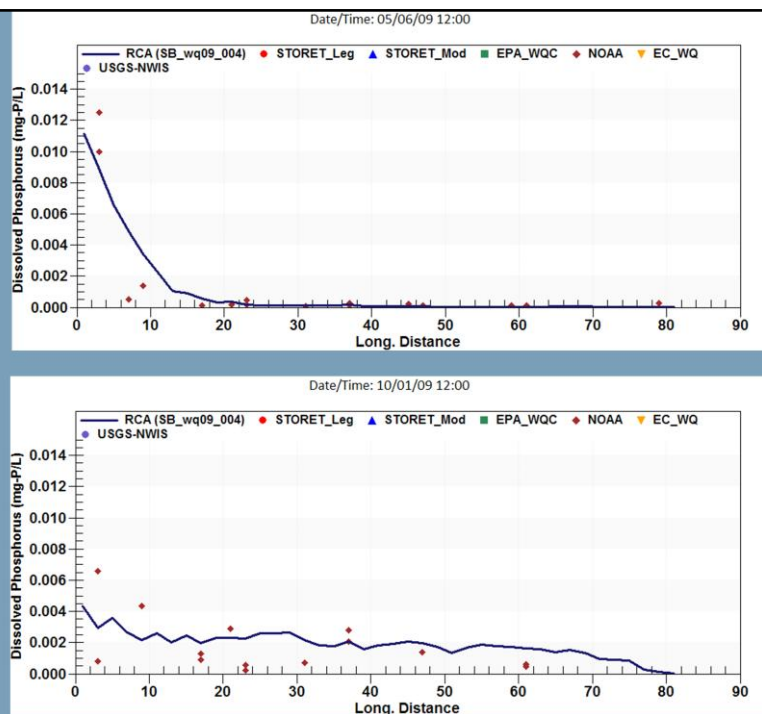


TP longitudinal profiles (laterally averaged) on two days in 2009. Wind-driven resuspension not included in run – wind event in early October not captured by model.



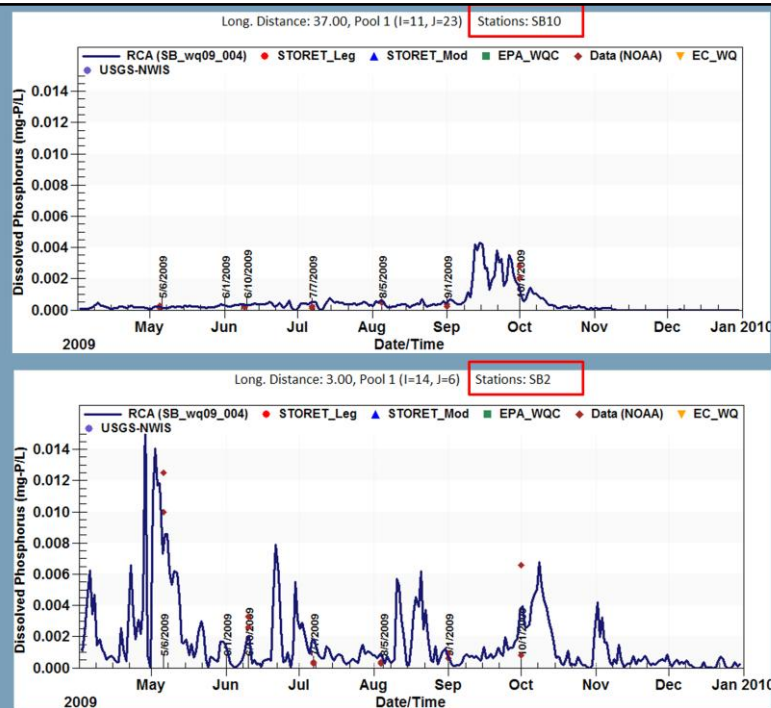
Time series TP comparisons with data at two stations.

Dissolved Inorganic Phosphorus (longitudinal profiles)

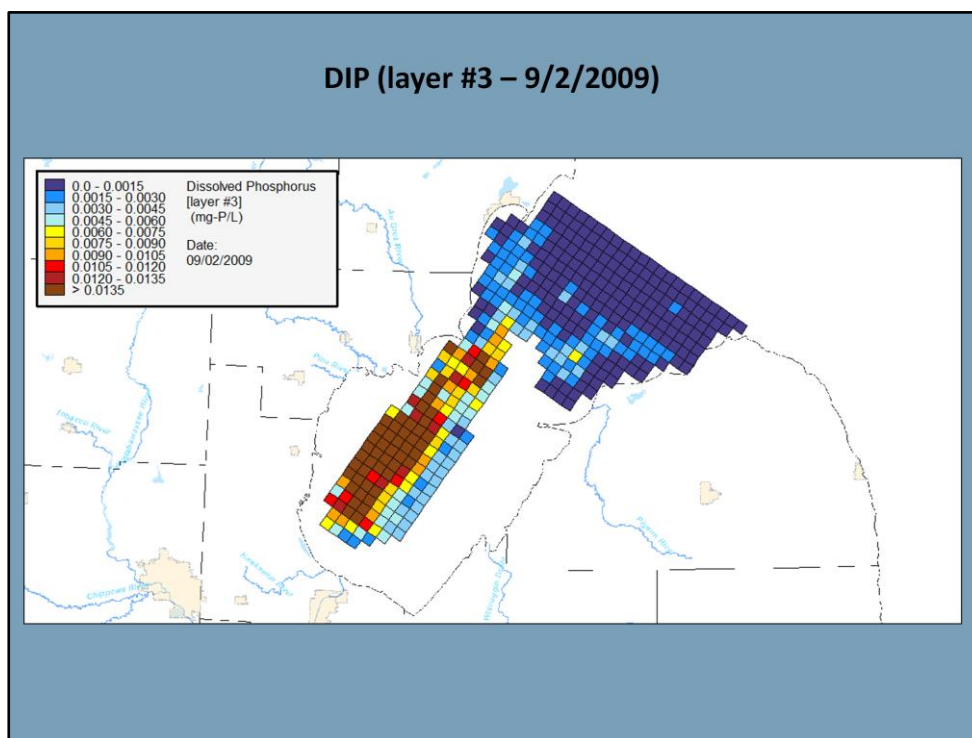


Dissolved inorganic P longitudinal profiles (laterally averaged) on two days in 2009. May simulation day is during a high Saginaw River load.

Dissolved Inorganic Phosphorus (time series comparisons)

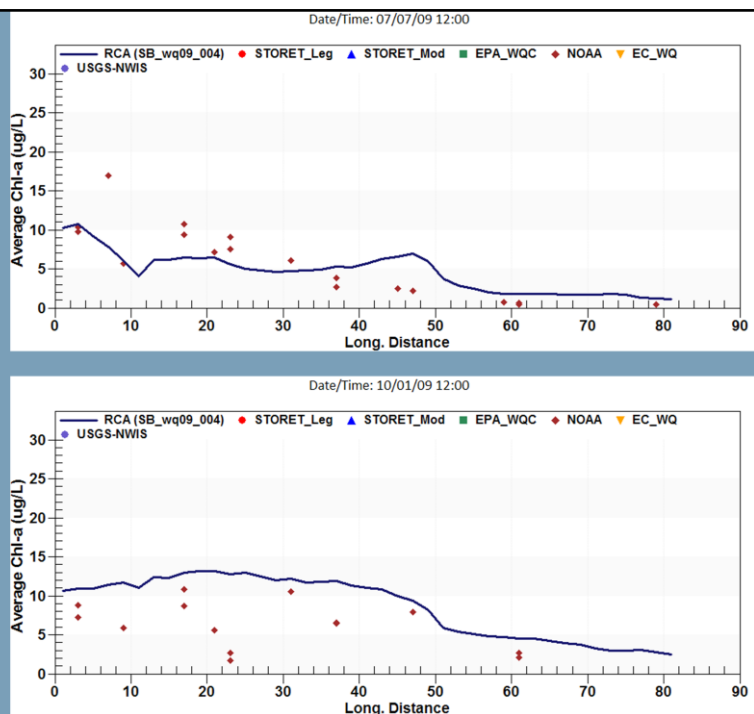


Time series DIP comparisons with data at two stations.



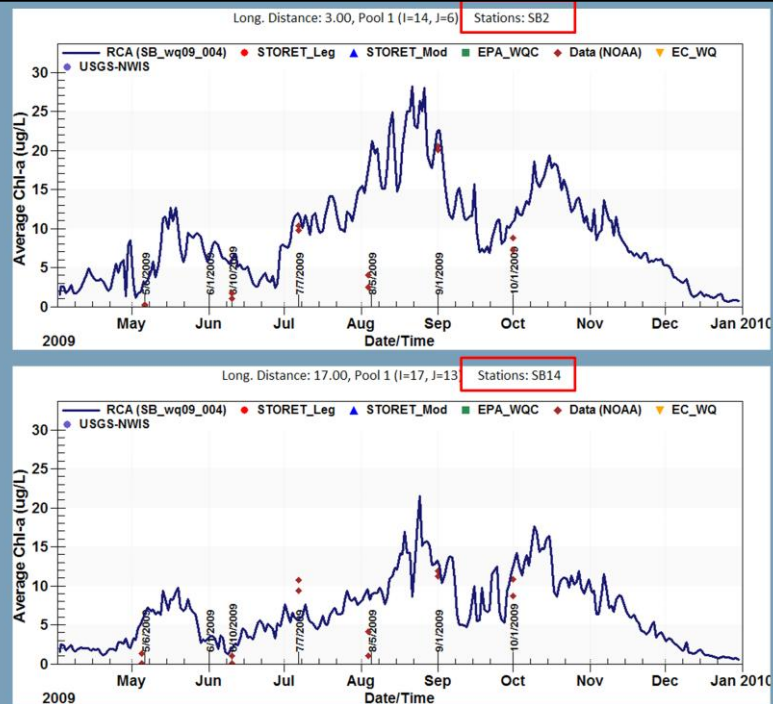
Model is computing sediment P release from deeper, more organic sediments in inner bay.

Total Chlorophyll-a (longitudinal profiles)

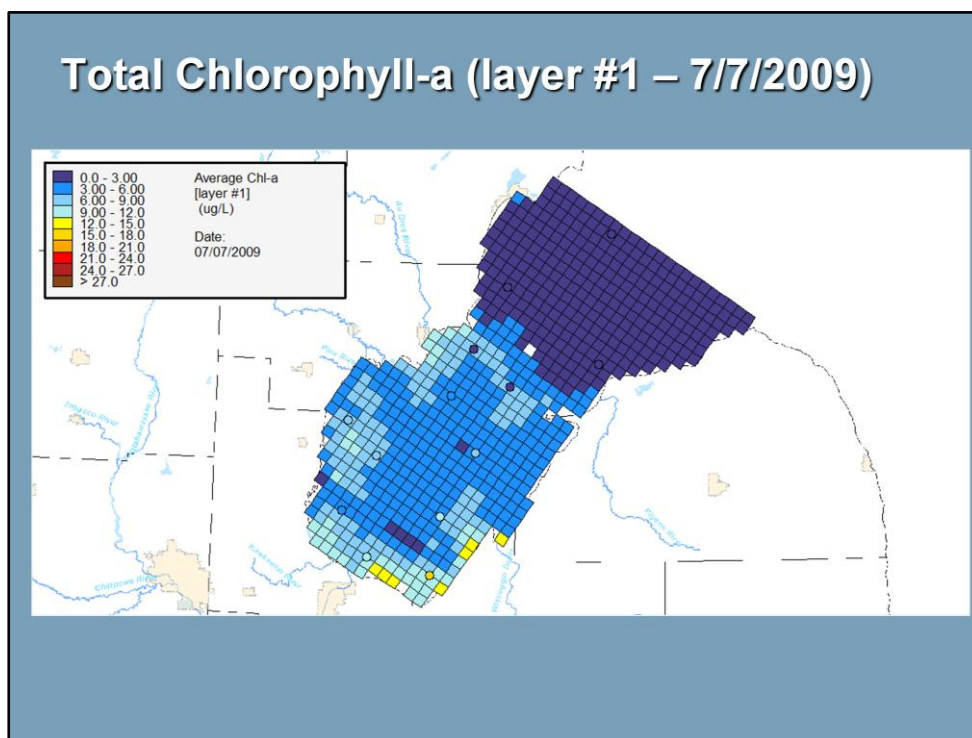


Chlorophyll-a longitudinal profiles (laterally averaged) on two days in 2009. Over-prediction in October may be related to inadequate light growth limitation from inadequate sediment resuspension.

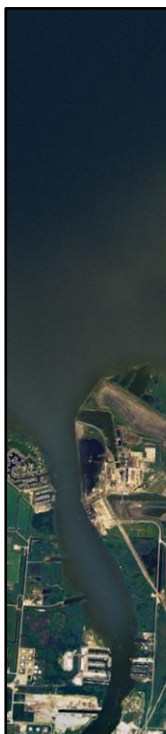
Total Chlorophyll-a (time series comparisons)



Slight over-prediction of chlorophyll in fall.



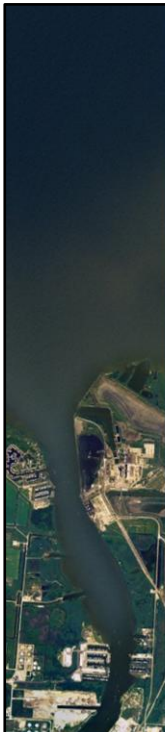
Model post-processor can also compare 2D map of simulation on a given day with the observations on that day.



SAGEM2 Development Plan

1. Build SAGEM2 model
2. Application to 1991-96 Saginaw Bay data
 - Preliminary calibration
 - diagnostic analysis
 - Provide feedback for AIF process
3. Final calibration with project data
 - 2009 – 2010
4. Confirm SAGEM2 with 2008 run
5. Link SAGEM2 with upper food web model (SB-IBM)
 - Produces SAGEM3
6. Apply to management questions within AIF process

Remainder of steps for SAGEM2 development and application in this project.



Management Application of SAGEM2

- Develop phosphorus load – response curves for endpoints of concern:
 - Summer average chlorophyll *a*
 - Peak *Microcystis* biomass
 - Total Cladophora production
 - Other endpoints
- Evaluate effects of other stressors on phosphorus load – response relationships
 - Dreissenid densities
 - Hydrology (wet vs. dry years)
 - Water level regime
 - Suspended solids loads
 - Temperature

Need to work with managers and other project team members to develop specific scenarios to run with model.



Management Application of SAGEM2

- Connect watershed management actions to Saginaw Bay ecosystem
 - Propagate watershed model load reduction scenarios through SAGEM2
 - Pass SAGEM2 output to Fish IBM

Need to work with managers and other project team members to develop specific scenarios to run with model.



1.5 more years for this project – remaining time will be spent modeling and analyzing data and using this to provide advice to managers. However, we will likely produce additional questions and data needs that might be undertaken in 2012 in Saginaw Bay.